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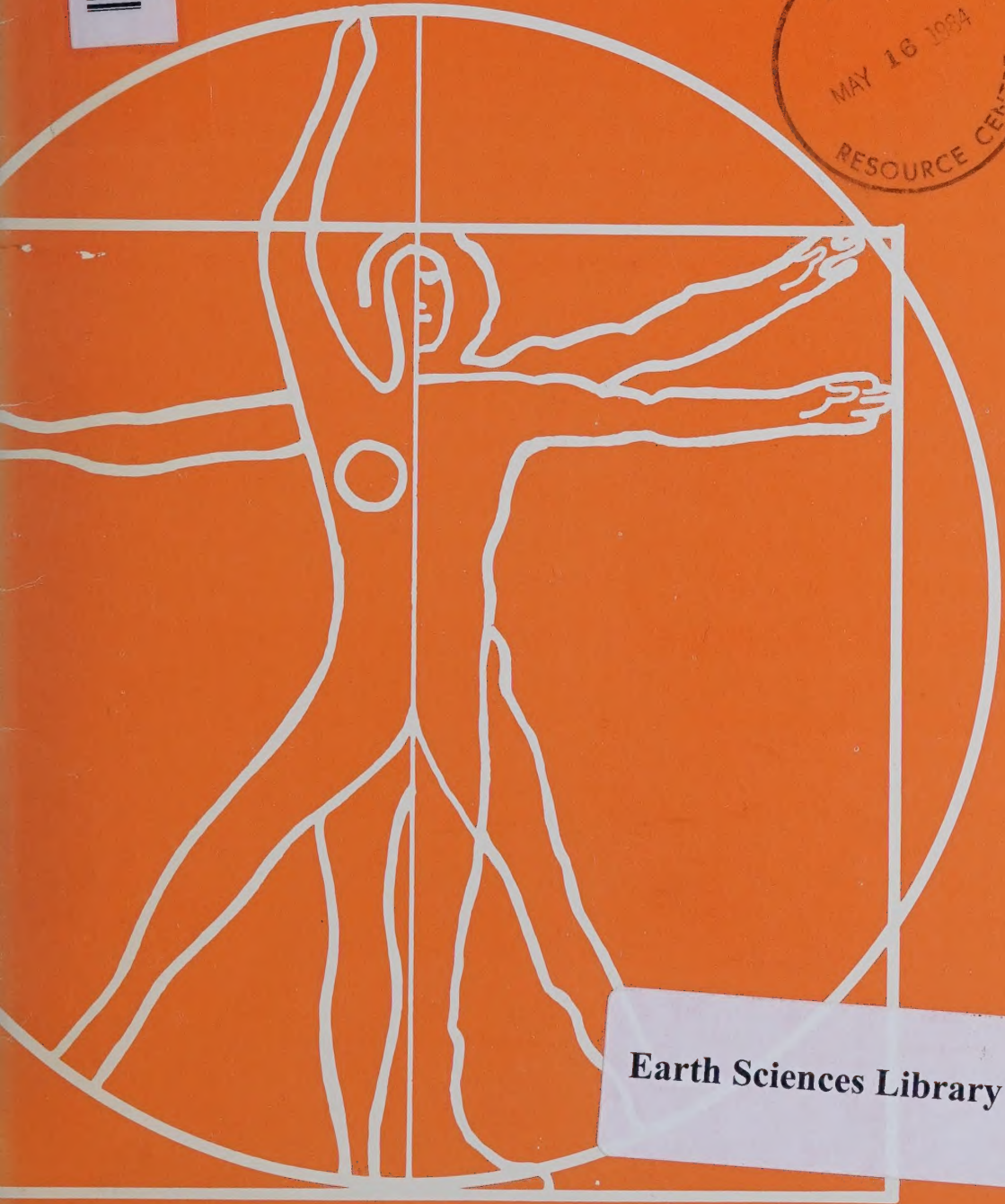
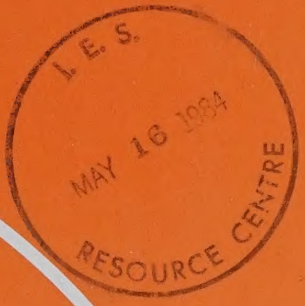
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an investigation of formaldehyde gas levels in houses in st. john's, newfoundland



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AN INVESTIGATION OF FORMALDEHYDE GAS LEVELS IN HOUSES IN
ST. JOHN'S, NEWFOUNDLAND



Environmental Health Directorate
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GEORTEC LIMITED

JUNE 1982

P.E. GEORGHIOU

D. SNOW

THE CONCLUSIONS AND RECOMMENDATIONS CONTAINED HEREIN REPRESENT
THE OPINION OF THE CONTRACTOR AND DO NOT NECESSARILY CONSTITUTE
ENDORSEMENT BY THE DEPARTMENT OF NATIONAL HEALTH AND WELFARE



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INTRODUCTION

The problems and potential problems associated with formaldehyde gas emitted from urea-formaldehyde foam insulation (UFFI) and from other sources in non-industrial indoor environments in Canada have been extensively documented^(1,2,3) and have received intensive press coverage recently. The analytical method used in the great majority of the determinations of formaldehyde levels up to now has been the method recommended by the National Institute for Occupational Safety and Health (NIOSH), Method P&CAM 125⁽⁴⁾. The method is sensitive enough but it is complex and a high degree of skill is required both for the on-site gas sampling and for the subsequent laboratory workup and analysis.

In November of 1979 we proposed to investigate the feasibility of using alternative methods to achieve a similar level of sensitivity and precision as that of the NIOSH method but which require less expertise. This is especially important considering the magnitude of the sample population that needs to be examined. Specifically, we proposed to evaluate in a field study the use of a portable single-beam infrared spectrophotometer, the Miran 1A General Purpose Gas Analyzer, manufactured by Foxboro Analytical. In the field study, formaldehyde levels measured with this instrument would be correlated with levels measured simultaneously by the NIOSH method. The instrumental method would be evaluated by examining a group of 50 houses in the St. John's area up to four times. In addition, a limited survey of relevant study home characteristics would be conducted by means of a questionnaire to be completed by the homeowner.

After only 30 houses were examined we found that no acceptable correlation existed between the NIOSH- and MIRAN-determined levels. The levels of formaldehyde observed in most cases were below the limits of sensitivity and precision possible with the MIRAN and furthermore the infrared method was also found to be susceptible to unidentified interferants. The study was therefore broadened to include a limited field evaluation of another on-site analyzer, the CEA 555, and the prototype of a passive formaldehyde dosimeter: the duPont "Pro-Tek" C-60 Formaldehyde Air Monitoring Badge, and also to establish other applications for the Miran.

PRINCIPLE OF THE NIOSH METHOD P&CAM 125⁴

A known volume of the air to be sampled is bubbled at a rate of 1.0 L.min^{-1} through two glass impingers which are connected in series and which each contain 20 mL of distilled water. The first impinger is reported to be capable of trapping 80-100% of the formaldehyde in the air if the sampling is conducted over a 1 to 3 h period. The second impinger is therefore employed to trap the residual amount of the formaldehyde in the air. The resulting solutions are each transferred into 25 mL-capacity culture tubes. Using a polyethylene wash bottle the interior of the impinger and the impinger stem is rinsed once or twice with 1-2 mL portions of distilled water and this washing is added to the respective culture tubes which are then sealed with parafilm and capped with screwcaps. A field blank is also obtained for each site determination. Prior to the analysis which ideally is conducted within 72 h of sample collection, the solution volumes are made up to 25 mL in order to standardize the volumes of the solutions being determined.

Two- (or four-) mL aliquots of these solutions are removed and are treated with 0.1 mL (or 0.2 mL) of a 1% aqueous solution of chromotropic acid. The solutions are thoroughly mixed by means of a vortex mixer and to these solutions are added 3.0 mL (or 6.0 mL) concentrated sulphuric acid. After the solution has cooled to room temperature the absorbance of the purple chromagen which is formed is measured at 580 nm, and is proportional to the concentration of the formaldehyde in the solution. The concentration can then be determined by reference to a standard curve which is prepared daily using standard formaldehyde solutions.

Apparatus

Standard midjet glass impingers of 25-30 mL capacity were used throughout the study. When two impingers were used in series they were connected to each other and to the sampling pump by means of ~ 15 cm lengths of Tygon tubing. A Bendix Super Sampler BDX-60 pump, or a LaMotte Model BD Code 1944 pump was used for the air sampling. The pumps were calibrated initially by means of a Precision Scientific Co. "Wet Test Meter", and daily by means of a standard 200 cm^3 graduated gas bubble flow meter, or a calibrated Matheson Model 603 rotameter. A Horizon 5965 colorimeter employing standard 10 mm round cuvettes and calibrated against a Perkin-Elmer Hitachi 139 UV-VIS spectrophotometer was employed. The PE-Hitachi spectrophotometer employing standard 10-40 mm cuvettes was also used for many of the determinations.

Results and Discussion

Typically, we obtained calibration lines with slopes of between 0.22 and 0.16 AU.mL. μg^{-1} (Absorbance Units/microgram per millilitre) for the Horizon colorimeter employing 10 mm path length cuvettes; and slopes of between 0.50 to 0.42 AU.mL. μg^{-1} for the P.E.-Hitachi 139 employing 20 mm path length cells. Table 1 summarizes the results of our survey using the NIOSH method.

The NIOSH procedure is stated to have an analytical detection range of 0.10 $\mu\text{g.mL}^{-1}$ to 2.0 $\mu\text{g.mL}^{-1}$, and the lower limit of sensitivity is taken to be an absorbance of the resultant chromagen solution of 0.050 AU above the blank absorbance. In principle, greater sensitivity over a blank can be achieved by employing longer sampling times in order to increase the total amount of formaldehyde trapped, assuming that the time-averaged value is the same; or by increasing the path length of the spectrophotometric cells or cuvettes used in the analyses. For example, a calibration curve using 10 mm cells in our labs has a typical slope of 0.20 AU.mL. μg^{-1} , as compared with 0.42 AU.mL. μg^{-1} using 20 mm cells, and 0.66 AU.mL. μg^{-1} using 40 mm cells*. Using these slopes, their corresponding intercepts, and the NIOSH criterion of sensitivity, the detection limit for a 60 L air sample is 0.085 ppm using 10 mm cells; 0.040 ppm using 20 mm cells, and 0.026 ppm using 40 mm cells.

Formaldehyde concentrations can still be determined with a precision of the order of $\pm 5\%$ between replicates even though their chromagen absorbances are below the NIOSH criterion. Thus, in Table 1, we have listed these values where the absorbances have been < 0.050 AU above the field blank but have quoted the calculated values in parentheses.

R. Miksch of the Lawrence Berkley Laboratory has recently reported a revised NIOSH procedure⁽⁵⁾. This method is based upon the use of freshly prepared 1% aqueous sodium bisulphite as the trapping solution in the impingers and also on a standardization of the mode of collection of the gas sample and transference of the resulting solutions. The calibration curve is derived from a standard solution prepared with solid sodium formaldehyde bisulphite. We experimented with this method and found that it does offer some practical advantages, particularly with regard to the standardization of sample collection in the field. However, no

* NOTE: Beer's Law should hold, in principle, but the values quoted here were obtained with different instruments and with different calibration solutions.

significant increase in the efficiency of formaldehyde trapping was found in replicate experiments which were conducted in the field and in the laboratory. We did however observe greater intra-sample variation with the sodium-bisulphite method. A significant improvement on the distilled-water method however could be obtained simply by heating the chromotropic acid-sulphuric acid-treated aliquot for 15 min in a boiling water heating bath. Test-tubes whose openings are covered with parafilm, or culture-tubes capped with Teflon-lined screw caps can be employed for heating the solutions. It was found when using the original method that the heat generated by the addition of the concentrated sulphuric acid is too variable and greater intra-sample variation in the analyses can be seen when the solutions are not heated. Experiments were then conducted to establish optimum pumping rates. No significant differences were observed in replicate (side-by-side) sampling for samples collected using flow rates of 0.50 L.min^{-1} , 0.75 L.min^{-1} , or 1.0 L.min^{-1} over suitable lengths of time. (see Table 2). For longer sampling periods (3-24 h) use of the 0.50 L.min^{-1} pumping rate is recommended since less formaldehyde is outgassed from the first impinger as determined by the relative amounts of formaldehyde trapped in the second impinger.

There has been considerable concern over the efficiency of the NIOSH procedure for trapping the ambient formaldehyde as it is being pumped into the liquid-filled impinger. We have conducted two experiments which confirm the efficiency of the trapping. These experiments are described elsewhere in this report.

PRINCIPLE OF THE MIRAN 1A GENERAL PURPOSE GAS ANALYZER

The Miran 1A General Purpose Gas Analyzer manufactured by Foxboro Analytical is a portable single-beam infrared spectrophotometer. It consists of an analyzer in which the infrared light is generated and is passed through a filter in order to select the required wavelength. The light of desired wavelength (for formaldehyde, a wavelength of 3.58 μm corresponds to its C-H stretching absorption) then passes into the gas cell which contains the air sample to be analyzed. The instrument also consists of a pump which pumps the air into the cell at a rate of 30 $\text{L}\cdot\text{min}^{-1}$. In the cell, the infrared light is reflected back and forth through the sample by means of suitably positioned mirrors. By adjusting the mirrors, the number of reflections of light through the sample can be reduced or increased such that an effective pathlength of between 0.75 to 20.25 m in increments of 1.5 m is achieved. Thus, the greater the number of reflections the more energy will be absorbed by the sample before the light reaches the detector.

The energy of the light reaching the detector is converted into an electrical signal which can be amplified and relayed to a meter or a strip-chart recorder. The amount of infrared energy absorbed by the molecules that a beam of infrared light collides with is a function of both the concentration of the absorbing molecules and the pathlength, and thus follows Beer's Law:

$$A = abc$$

where A = absorbance; a = absorptivity constant;

b = pathlength; and c = concentration.

Results and Discussion

The Miran must first be calibrated by measuring the absorbances of known concentrations of formaldehyde. A closed-loop calibration system is attached to the Miran and known amounts of formaldehyde are injected into the loop and the corresponding absorbances are noted. We employed a modification of the Foxboro headspace method⁽⁶⁾ in order to obtain more reproducible and accurate determinations for low-level formaldehyde concentrations. Thus, a short piece of thick-walled tygon tubing is used in place of the teflon tubing which is normally used with the closed-loop device. In this way, we could insert the needle of a microlitre syringe containing 5-10 μL amounts of a methanol-free formaldehyde solution (obtained from paraformaldehyde and water), directly into the tubing, and slowly introduce fixed aliquots of a solution whose concentration could be accurately determined using the

standard iodometric method. The small amounts of solution relative to the volume of the closed-loop calibration system rapidly volatilized and the absorbance at 3.58 nm could be determined with the aid of a strip-chart recorder. Thus we found that $0.00425 \text{ AU} \pm 0.000250$ (17.5 recorder units ± 1.0) using the 0 - 0.025 AU range corresponded to $1.0 \text{ ppm} \pm 0.10 \text{ ppm}$. These values correspond well with the values reported by Foxboro Analytical using their own method where $1.0 \text{ ppm} = 0.0044 \text{ AU}$ (analysis of 26/V/1978, Foxboro).

The essential point to note about our own data however is that the noise level of the instrument is of the order of magnitude of the range of ambient levels that we are concerned with being able to detect.

Nevertheless, we felt at the onset that with sufficient care being exercised during the on-site field determinations, we would be able to observe and note significant absorbances over the zero-gas base-line levels. A base-line level for the particular location can be determined by the use of pre-activated charcoal filters which are inserted at the end of the inlet sampling hose. In the laboratory it was established that fresh or pre-activated (100°C activation 6-10 h) charcoal filters were extremely efficient in absorbing formaldehyde from the air being analyzed in the gas sample cell. Experiments showed that there was no absorption of water vapour from the sampled air by the charcoal filter. (Water vapour constitutes a likely interferant at the wavelength of interest.) Thus, we were convinced that a suitable base-line could be achieved for each of the sampling locations by allowing a 15-30 min equilibration time for the Miran, and inserting the charcoal filter at the front of the inlet hose and sampling in this mode for 5-10 mins. Once a stable base-line was noted by means of the strip-chart recorder, the charcoal filter was then removed and any deviation from the base-line could be recorded over a 5-10 min period. The charcoal filter is then reintroduced and the new base-line noted. Table 3 illustrates the values obtained when the Miran and NIOSH methods were used simultaneously. A poor correlation exists between the methods for the low range of formaldehyde concentrations being observed. It is our opinion therefore that the Miran is not a reliable indicator of levels of $< 0.20 - 0.25 \text{ ppm}$ formaldehyde in air. Instrumental noise and typical base-line drift is of this same order of magnitude. In addition, however, the Miran also appears to be susceptible to some as yet undetermined interferants, possibly hydrocarbons see e.g., houses #28 and #29, Table 3. For these reasons the Miran is not suitable for either single point determinations or longer-time monitoring of indoor air formaldehyde levels.

We did note several very useful applications for the Miran however. It is well-known that wall-cavity formaldehyde levels are of an order of magnitude larger than those normally found in the room. The Miran was thus employed to monitor wall-cavity formaldehyde levels directly.

In a series of experiments conducted in July and August, the Miran was connected to a wall cavity via a short length of tygon tubing containing a simple automobile in-line filter. The wall cavity could then be monitored continuously over a 48-72 h period. The exit gases were vented from the exit port to the outside via a 10-15 m length of tygon. One could clearly observe a regular increase in the absorbance of the sampled air from the wall cavity as the exterior wall was being heated by the sun, indicating increasing formaldehyde outgassing. The levels indicated correlated well with the NIOSH-determined levels for the same cavity, utilizing the same hole. In a parallel study, 1.0 h room air samples were being collected. The fluctuation in the formaldehyde levels in the room air as determined in this way, closely paralleled that observed for the wall cavity although there appeared to be a lag period. As the exterior walls cooled so the observed formaldehyde levels decreased both in the wall cavity as observed with the Miran, and in the room air as measured by the conventional NIOSH method. In fact, we were able to gain direct experimental evidence of the effect of sunlight on exterior walls and the resulting elevation of formaldehyde levels in the corresponding room air. The effect can be quite dramatic and we were able on several occasions to note as much as 2 to 3-fold elevation of formaldehyde levels by the NIOSH method in one part of the house even though the internal temperature and humidity levels appeared not to differ significantly.

A further important application of the Miran has been with regard to establishing the correlation between Drager formaldehyde tubes and the NIOSH-determined levels. A report on this parallel study has already been submitted to the N.R.C.

During this study we employed the Miran as a sampling pump by connecting a needle valve in series with the Miran pump and an impinger. The impinger in turn was connected to the wall cavity via the tygon tubing containing the in-line filter. Using a bubble flow meter, we obtained a flow rate of $1.0 \text{ L} \cdot \text{min}^{-1}$ through the impinger which initially contained no distilled water. This gave an absorbance due to the formaldehyde outgassing from the wall cavity which could be monitored on a strip-chart recorder. A level of $\sim 2.0 \text{ ppm}$ could be observed. The impinger was then filled with 20 mL of distilled water in order to trap the outgassing formaldehyde. The absorbance virtually disappeared and the zero base-line was maintained during a 1 h sampling

period. Noting that the instrumental noise is of the order of ± 0.2 ppm we conclude that the single impinger can trap $> 90\%$ of the formaldehyde. We thus have direct visual evidence here for the efficiency of the trapping in the NIOSH-procedure (we were able to demonstrate the same finding using the CEA 555 instrument in an identical mode).

We employed the Miran in a test room in which known amounts of paraformaldehyde were volatilized and thus the room air concentration could be calculated. Simultaneous NIOSH determinations were conducted. The Miran clearly showed a decrease in the formaldehyde concentrations over a 3 h period, presumably due to air changes occurring in the room. However, the time-averaged Miran absorbances agreed well with the NIOSH-determined level over a similar time span. Thus the Miran could be used to establish ventilation rates and indeed, we noted in a recent publication by R. Miksch⁽⁷⁾ that a similar instrument has been used for this very purpose using sulphur hexafluoride as the tracer gas⁽⁸⁾. Our own findings suggest that a hydrocarbon such as propane, or a volatile alcohol such as ethylalcohol, or isopropanol can be used just as effectively as a tracer. Thus, the rate of decrease of the absorbance due to a known amount of the compound being employed as the tracer in the room in question, can be observed directly.

PRINCIPLE OF THE CEA 555 AIR MONITOR

The CEA 555 Air Monitor is an automated portable wet chemical colorimetric analyzer that can be used to analyze for the presence of various gases, including formaldehyde. The air sample which is being analyzed is drawn into the instrument via an internal vacuum pump and through a helical glass gas-liquid contact absorber column. An absorbing solution of sodium tetrachloromercurate containing a fixed quantity of sodium sulfite is fed in a concurrent stream through the column to absorb the formaldehyde from the air stream. The resulting solution is transported into the system where it is combined with a solution of pararosaniline which reacts with the formaldehyde to produce a color. The chromogen is then transported to a colorimeter which measures electronically the difference in color of the added pararosaniline solution before and after the reaction with the formaldehyde. The intensity of the colour formed obeys Beer's Law and, using a strip-chart recorder connected to the instrument, these differences can be recorded. Comparisons are made with reference to a calibration curve obtained with known standards. There has been controversy with regard to the mechanism of the reaction and Miksch suggests⁽⁷⁾ that the toxic sodium tetrachloromercurate solution can be eliminated from the procedure, altogether. The order of addition of the reagents need only be reversed and we are currently investigating the feasibility of doing this with the CEA 555.

Results and Discussion

We have conducted only a limited investigation of the CEA 555 up to now but, in general, employing some of Matthews'⁽⁹⁾ recommendations, we have noted a good correlation between NIOSH-determined and CEA 555-determined formaldehyde levels. The instrument however requires a considerable amount of operator skill and the reagents are costly. A maximum of two homes per day can be measured using the instrument and we recommend that an on-site calibration be conducted for each home. The major advantage of the CEA 555 is that it offers a direct, visual, on-site record of indoor levels. In addition, it can be used with suitable minor modifications to monitor typical non-industrial indoor formaldehyde levels on a continuous basis.

We employed the CEA 555 with a strip-chart recorder in a preliminary experiment to establish the efficiency of formaldehyde absorption by an impinger containing distilled water. (A similar experiment was conducted with the Miran 1A - see above.) The CEA 555 base-line level was established using a zero gas charcoal filter on the inlet of the air sampling pump which was set for a flow rate of 0.75 L.min^{-1} . The charcoal filter was then removed and after ~10 min a new level

was established corresponding to the concentration of formaldehyde gas present in the test room. A short piece of tygon was employed to connect the side outlet of a glass impinger containing 20 mL of distilled water, to the air sampling pump inlet. The flow rate of the instrument was confirmed by using a bubble flow meter connected to the impinger while in this mode. Within 10 min the absorption level established for the room formaldehyde concentrations decreased until the original base-line was re-obtained. Within the limits of uncertainty due to instrumental noise, a 95% efficiency of formaldehyde trapping in distilled water over a 1 h period could be discerned. Analysis of the resulting solution was in agreement with the CEA 555-determined level.

Results and Discussion

We have conducted only a limited investigation of the EA 555 up to now but, in general, employing some of the procedures⁽¹⁾ recommended here, we have obtained a good correlation between the instrument and the 555-determined formaldehyde levels. The instrument however requires a considerable amount of operator skill and the readings are noisy. A number of the factors that can be minimized using the instrument and we recommend that an operator utilizing the instrument for this work. The major advantage of the EA 555 is that it gives a direct, accurate, sensitive record of indoor levels. In addition, it can be used with suitable modifications to monitor typical non-industrial indoor formaldehyde levels in a continuous basis.

We employed the EA 555 with a strip-chart recorder in a preliminary experiment to establish the efficiency of formaldehyde absorption by an impinger containing distilled water. A similar experiment was conducted with the EA 555 and the results are shown in Figure 1. The EA 555 base-line level was established using a zero gas standard. The flow rate of the air sampling pump which was set for a flow rate of 10 L/min. The standard filter was then removed and after 10 min a new level

PRINCIPLE OF THE DUPONT PRO-TEKTM FORMALDEHYDE AIR MONITORING BADGES, SERIES II, TYPE C-60

The Pro-TekTM formaldehyde badge is a diffusion monitor which collects formaldehyde from the air. This is achieved by means of a specially-designed wick which is connected to a pouch containing approximately 2.0 ml of a 1% solution of sodium bisulphite. The wick absorbs formaldehyde from the air in which the badge is located and traps it as the bisulphite adduct. The badges are pre-calibrated in the factory on a batch basis by analysing badges from the batch which have been exposed to known formaldehyde levels for known periods of time. Thus, each batch possesses a specific calibration factor. The analyses of the resulting solutions are conducted by the usual chromotropic acid-sulphuric acid procedure. The time weighted average (TWA) formaldehyde concentration is calculated by subtracting the absorbance value obtained for an unexposed badge solution from the absorbance value obtained for an exposed badge solution⁽¹⁰⁾:

$$\text{TWA ppm} = \frac{\text{Sample Absorbance} - \text{Blank Absorbance}}{\text{Calibration factor} \times \text{Total hours exposed.}}$$

The calibration factor is dependent on the path length of the cells employed in the analysis at 580 nm. Thus, using 40 mm cells and a calibration factor of 0.0566 AU per ppm-hour, and the NIOSH criterion of 0.050 AU above a blank we estimated initially that a 24 h exposure would suffice for the average levels (e.g., 0.050 ppm) being observed in the homes which had been surveyed.

$$\text{i.e., assuming a TWA} = 0.050 \text{ AU} = \frac{\text{Absorbance Difference}}{0.0566 \times 24}$$

$$\text{Absorbance Difference} = 0.068 \text{ AU}$$

Results and Discussion

We designed our experiment to establish the correlation between NIOSH-determined levels in some of our survey homes and those indicated by the duPont badges. Twenty homes were selected from our list, including controls. Two badges were sent to each home each with detailed instructions on their deployment. One was to be worn on a member of the household while the other was to be placed on a wall in a room in which we had conducted our NIOSH-determinations. The deployments were synchronized with a visit by our field team to those houses so that a third badge carried to the home by the field team could be placed by them adjacent to the one which we sent to the homeowner by mail. At the same time, a NIOSH measurement was

conducted using different sampling periods. On the next day, our field team collected the badge which they deployed and the homeowners were requested to return their ones to us by mail. Table 4 summarizes the results. Recipients #1-10 had badges mailed to them with no follow-up conducted by our group. With the exception of recipient #4 the observed levels do not appear to be unusual. However there was no way of confirming these observations.

Recipients #11 to 30, however, generally had a concurrent NIOSH test conducted and/or the deployment of a third badge by our field team. The discrepancies between the NIOSH-determined levels and those obtained for the badges are readily apparent. However, one can note (Recipients #11; 12; 16; 17; 20; 21; 29) generally good agreement between those badges taken, deployed and returned by the field team and the NIOSH values obtained. The badges generally and consistently record higher TWA's. There was a very poor correlation between NIOSH and badge-determined levels for those which had been through the mailing system and which had been deployed by the homeowner. Initially we suspected damage due to the initial mailing processes involved. But, it became apparent after further experimental data was obtained that there was no practical method of knowing the blank value for the particular individual badges. Examination of several unexposed blank badges showed that the zero values after chromotropic-sulphuric acid treatment varied over a 40% range, with the absorbances of some blanks being comparable to those of some of field deployed badges. With longer exposure (up to seven days), however the accumulated amounts of formaldehyde would, after chromotropic acid-sulphuric acid treatment, result in higher absorbance values. Thus the differences due to inter-badge blank variations would become relatively insignificant. The remaining badges were, therefore, deployed for exposures of up to a seven-day period in several of the test houses. For those cases the correlation with the NIOSH-determined levels was excellent.

An analysis of variance was conducted using a blocking procedure in which the duPont badges were compared with the NIOSH method for each of the test environments. The best correlation obtained between the NIOSH-determined levels and those from the duPont badges was from the experiments in which badges were exposed for periods equal to or greater than 72 h, and in which NIOSH samples ranging from 3-24 h were collected. At the $\alpha = 0.05$ level the two methods were statistically indistinguishable.

It must be recognized however that this type of correlation will not necessarily be found for all environments, since we recognize the limitations of a single NIOSH determination. Furthermore, with the prototype badges which we employed one can only approximate the blank absorbance values since in effect the absorbing solution for the determination is unique for each badge. duPont have since produced an improvement on these badges by having two pouches containing the same solution per badge, one of which will be used for the formaldehyde absorption and the other which will be exposed to the same environmental conditions except for the actual exposure to the air being monitored.

SURVEY RESULTS

The homes surveyed were chosen from a list of homeowners who had contacted us prior to the commencement of the study. Control homes were selected on the basis of their similarities in age to the majority of the homes which were under study and on the basis of personal contact. In only one of the control homes was there a resident who smoked. All homeowners were asked to keep doors and windows closed for a minimum of 24 h prior to the sampling. Several homes were selected for long-term investigation on the basis of an unusually high formaldehyde level being observed during the initial surveys. See Tables 1 to 5.

The histograms shown in Figure 1 show some correlations for the houses surveyed. Eighty-four percent of the houses insulated in 1979 or later had a NIOSH-measured level of > 0.06 ppm on at least one occasion. Of the sample group, fifty-eight percent had a measured level of ≥ 0.1 ppm on at least one occasion. By comparison, of those houses which were insulated during 1978, forty-four percent had levels > 0.06 ppm measured on at least one occasion, and only one house in this group had a formaldehyde level of ≥ 0.1 ppm measured on at least one occasion. Of the houses insulated prior to 1978 only twenty-two percent had levels of > 0.06 ppm measured on at least one occasion, and none of the houses in this group had ≥ 0.1 ppm level on any occasion.

Whether the observed trend of a decrease in the measurable levels with time will be continued can only be speculated upon. However, it is known that over a 9-month period to date several of the original survey homes still have high measurable levels. It is our opinion that the known formulation changes which resulted in the production of a denser UFFI could be responsible for the relatively high degree of formaldehyde outgassing observed in the 1979-insulated houses. Furthermore, it is our opinion that these levels will not decrease as dramatically over only one or two years.

The histograms in Figure 2 show the correlation between the dates of UFFI installation and reported health-related complaints. No attempt has been made to evaluate this correlation on an epidemiological basis.

Variations in the measured formaldehyde levels are clearly discerned in many cases. These variations can be due to several identifiable causes:

- (a) Errors introduced during the sample collection and analysis: a potential variation of as much as $\pm 15\%$ can be accounted for simply due to errors of calibration of the pump flow rate ($\pm 5\%$), the process of transferring

solutions from the impingers in the field ($\pm 5\%$) and, variations encountered due to the analytical procedures ($\pm 5\%$). However, under a stringently controlled protocol an overall precision of $\pm 10\%$ is possible.

- (b) External climatic conditions. Since the major source of formaldehyde gas in UFFI homes is due to infiltration of air through wall cavities relative pressurization conditions are important⁽¹¹⁾. Conditions of high winds, high temperatures and high relative humidities are all factors which contribute to formaldehyde gas elevation in the living spaces of homes.

The most direct effect that has been recorded on several occasions during the study has been that of direct sunlight on the UFFI-containing exterior walls. Thus, in one series of experiments conducted in house #24 a level of < 0.04 ppm was recorded in one room and two hours later a level of 0.36 ppm was observed in the same location. The room had a North-facing UFFI-wall and the first measurement was conducted between 9:30 and 11:30 a.m. The second was conducted between 1:30 and 3:30 p.m. with the sun shining directly onto the wall. The experiment was repeated several days later when levels of 0.080 ppm and 0.16 ppm respectively were recorded in the same room. We have noted the same effect in another home, #19, in which the test room had a South-facing UFFI-filled wall. In this location, the morning levels were higher than those made in the afternoon. Levels of 0.16 ppm and 0.092 ppm were noted for the morning and afternoon determinations, respectively. We have noted this effect during continuous monitoring over 6-7 day periods in conjunction with current experiments which we are conducting and which are designed to further evaluate the duPont Pro-TekTM formaldehyde monitoring badges.

In general, the highest levels observed among the four determinations per home have also had the highest simultaneous recording of internal temperatures and relative humidities. These also parallel external temperature and relative humidities during the summer conditions. We have also noted that within multi-level houses the highest levels measured during simultaneous determinations are found in the upper storeys. This is particularly evident in cooler weather. During the warmer months the levels appear to be more homogeneous throughout the buildings.

Another observation that we were able to make is that in three of the houses in which levels of 0.1 ppm or greater were observed there were regions of UFFI which were exposed to the interior of the house at some location. There were many cases in which UFFI had been installed in regions not recommended for UFFI use e.g., around chimney mortar, basement sills and overhangs and in one case in an attic although in the latter case the levels were not high (house #18).

CONCLUSIONS

1. The Miran 1A is not sensitive enough for the measurement of formaldehyde levels in the indoor air of non-industrial environments. It is however suitable for the measurement of the formaldehyde levels associated with the outgassing of UFFI in wall cavities and in this context correlates well with NIOSH-determined levels. A further application is for investigation of ventilation rates.
2. The CEA 555 offers some advantages in that it is more sensitive than the Miran 1A and is a direct on-site measuring device which is also capable of being used as a continuous monitor. However, it requires a high degree of skill to calibrate and maintain, and employs relatively expensive chemicals. It does offer a major advantage in that a visual record is available to the concerned homeowner immediately upon completion of the testing.
3. The precision of the NIOSH or any other method employed is limited to the degree of actual fluctuation in the indoor formaldehyde levels which is dependent upon external and internal conditions. In this regard the variance in ventilation rates have been found to be generally larger than those found for the variance in the measurement of formaldehyde levels for a particular environment⁽⁷⁾. Thus single NIOSH or CEA 555 determinations for homes in which a standardized protocol has been followed will not necessarily indicate "worst-case" indoor formaldehyde levels.
4. Passive-type dosimeters which monitor levels over an extended period in the particular environments offer a more meaningful time-weighted average of formaldehyde levels which residents would be exposed to. The problem of variations in the background (blank) levels of the solutions used in the individual dosimeters remains a major obstacle to the method, at present.
5. There appears to be a group of UFFI-homes in which formaldehyde levels are unusually high.

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Table 1
SURVEY RESULTS

House #*	Date (1981)	Indoor T(°C) %RH	Outdoor T(°C) %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)
1	9/VI	20	54	99.2	24	M	<0.25
1	8/VII	20	58	98.8	30	80	(0.05
1	14/VII	18	62	101.8	20	90	(0.01)
1	1/IX	20	69	102.2	11	240	0.045
2	9/VI	18	60	99.2	22	M	0.3
2	8/VII	23	60	99.9	30	80	(0.02)
2	11/VIII	20	67	102.0	5	60	(0.02)
2	1/IX	20	66	102.0	14	180	0.029
3	7/VII	22	66	101.9	26	60	(0.025)
3	15/VII	17	70	101.7	41	75	(0.02)
3	16/VII	21	66	101.4	30	90	0.058
3	21/XII	23	58	101.6	28	120	(0.044)
4	1/IV	24	59	100.2	26	60	0.11
4	17/VII	29	52	101.4	30	45	(0.04)
4	24/VII	20	61	102.0	19	120	0.042
4	21/XII	19	52	98.1	56	180	0.10
5	25/V	19	65	99.9	30	60	(0.04)
5	28/VII	19	65	101.3	24	60	(0.04)
5	4/IX	18	74	102.9	9	60	(0.03)
5	9/IX	20	72	102.1	26	60	(0.02)
6	1/IV	20	76	100.2	15	60	(0.02)
6	20/VII	21	65	101.3	5	80	(0.04)
6	4/IX	19	60	103.0	12	60	(0.02)
6	9/XII	16	75	99.1	9	180	(0.03)

Table 1 (cont'd)

House #*	Date (1981)	Indoor T(°C) %RH	Outdoor T(°C) %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)		
7	1/VI	23	60	13	89	100.2	26	60	0.05
7	7/VII	20	66	19	33	100.0	26	140	0.03
7	20/VII	20	58	15	80	101.3	5	60	(0.04)
7	9/IX	21	74	12	80	102.1	26	60	(0.04)
8	5/V	16	66	7	90	99.1	13	60	(0.04)
8	5/VI	18	65	7	85	100.2	25	M	0.25
8	28/VII	16	69	14	95	101.1	20	60	(0.03)
8		Refused 4th Test							
9	8/VI	17	58	13	89	98.6	30	M	< 0.25
9	20/VII	21	60	16	83	101.3	5	60	(0.05)
9	9/IX	21	70	12	88	102.0	20	60	(0.05)
9	10/IX	21	70	11	86	102.0	24	60	0.10
10	8/VI	22	54	14	80	98.7	30	M	< 0.25
10		House sold, new owner refused testing.							
10									
10									
11	2/VI	23	59	9	63	101.5	32	60	(0.03)
11	8/VII	23	60	21	70	99.9	30	60	(0.03)
11	29/VII	21	58	16	63	100.8	50	60	(0.03)
11	1/IX	22	60	18	80	102.3	9	180	0.076
12	8/VI	24	68	14	80	98.6	30	M	< 0.25
12	16/VII	21	65	16	73	101.4	45	60	0.07
12	4/VIII	26	62	23	69	101.9	24	61	0.11
12	22/VII	20	46	3	75	101.3	45	120	(0.05)
13	15/VI	22	54	17	75	101.8	30	60	0.07
13	9/VII	18	62	10	81	99.8	13	175	0.069
13	19/VII	21	65	25	48	101.3	15	190	0.063
13	25/VIII	20	68	9	85	101.1	24	60	0.08

Table 1 (cont'd)

House #*	Date (1981)	Indoor T(°C) %RH	Outdoor T(°C) %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)
14	17/VI	28	55			60	(0.02)
14	24/VII	25	50	101.9	10	63	0.08
14	20/VIII	22	76	101.7	15	340	0.064
14		Refused final test.			19		
15	11/VI	21	74	98.8	36	60	(0.01)
15	23/VII	22	65	101.1	35	60	(0.03)
15	2/IX	19	70	102.9	8	1440	0.018
15	21/XII	23	58	100.6	28	120	(0.04)
16	25/V	22	54	99.1	13	60	.07
16	10/VII	19	62	100.1	20	127	.043
16	3/VIII	30	58	101.5	35	60	0.11
16	21/XII	19	68	100.4	39	120	(0.04)
17	22/V	20	68	102.1	10	60	0.06
17	17/VII	20	70	101.4	20	75	0.07
17	1/IX	18	70	102.2	14	164	0.062
17	22/XII	16	58	101.3	46	180	0.033
18	9/VII	21	56	99.2	61	100	(.02)
18	8/IX	18	72	101.4	30	60	(.05)
18	9/IX	19	73	101.4	30	60	(.03)
18	10/IX	18	72	101.4	28	60	(.05)
19	5/VII	21	52	101.4	20	120	0.071
19	11/VII	22	58	100.5	13	60	.09
19	25/VII	24	48	102.2	24	210	(0.02)
18	9/XII	18	58	99.1	9	180	0.11
20	20/V	16	52	101.1	28	60	(0.03)
20	4/VII	22	58	101.1	40	60	0.13
20	9/VII	17	62	99.8	13-22	60	0.08
20	11/VII	15	67	100.5	13	60	0.06

Table 1 (cont'd)

House #*	Date (1981)	Indoor T(°C)	Indoor %RH	Outdoor T(°C)	Outdoor %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)
21	17/V	18	60	5	88	100.1	20	60	(<0.01)
21	10/VII	15	70	14	87	99.9	19	180	(<0.01)
21	24/VII	18	56	14	67	101.9	15	60	(0.02)
21	21/XII	20	62	0	80	101.4	39	180	0.036
22	26/V	22	56	13	65	101.2	30	60	(0.01)
22	9/VI	19	64	12	80	99.2	22	M	0.25
22	15/VII	15	71	16	98	100.5	59	60	(0.01)
22		Unable to contact for 4th visit.							
23	2/VI	17	71	12	52	101.5	28	60	.09
23	14/VII	17	70	16	73	101.8	23	60	.09
23	11/VIII	18	71	17	85	102.0	16	180	.20
23	12/VIII	18	71	20	75	102.0	11	180	.22
24	4/VI	20	62	6	71	100.7	30	M	0.50
24	17/VII	22	64	21	50	101.4	30	60	.10
24	29/VII	21	60	18	54	100.8	50-70	60	.360
24	3/VIII	27	60	27	50	101.4	37	60	.150
25*	9/VI	18	60	12	78	99.2	22	60	(<0.01)
25	11/VII	19	58	17	85	102.1	16	60	(<0.01)
25	3/VIII	25	60	27	50	101.0	37	60	(<0.01)
25	21/XII	25	58	-2	80	101.2	28	60	(<0.01)
26*	9/VI	20	60	12	80	99.2	22	60	(<0.01)
26	3/VIII	27	52	19	70	101.5	32	180	(0.02)
26	11/VIII	20	76	16.5	88	102.1	16	180	(0.02)
26	8/IX	20	72	11	90	101.5	30	60	(<0.01)
27	8/VI	23	53	14	85	98.6	33	M	<0.25
27	16/VII	22	67	13	90	101.0	30	60	(0.02)
27	23/XII	18	56	1	96	100.55	19	180	0.045
27	23/XII	18	56	1	96	100.5	19	180	0.066

Table 1 (cont'd)

House #*	Date (1981)	Indoor T(°C) %RH	Outdoor T(°C) %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)
28	2/VII	25	17	101.4	32	60	0.16
28	21/VII	24	15	101.38	18	60	(0.04)
28	22/VII	24	16	101.2	23	70	(0.03)
28	3/VIII	27	27	101.4	37	120	0.065
29*	3/VI	18	16	101.4	36	60	(<0.01)
29	2/VII	25	17	101.2	32	60	(<0.01)
29	21/VII	26	17	101.3	30	75	(<0.01)
29	20/XII	22	1	100.5	20	120	(<0.01)
30	27/V	20	7	101.7	20	60	(0.03)
30	3/VIII	27	26	100.5	35	120	.065
30	11/VIII	24	20	101.9	9.5	220	.049
30	19/VIII	23	17.5	101.1	23	165	.066
31	22/V	23	10	102.1	21	60	(0.04)
31	17/VII	20	15	101.4	20	60	(0.05)
31	1/IX	20	18	102.3	15	240	0.12
31	9/IX	20	21	101.9	25	120	0.070
32	15/V	21	15	100.3	30	60	.10
32	14/VII	19	13	101.7	30	60	(<0.01)
32	8/IX	21	11	101.5	30	60	(.05)
32	8/IX	21	11	101.5	30	60	(.05)
33*	4/VII	28	21	101.0	5	60	(.01)
33	11/VII	17	13	100.5	15	60	(.01)
33	8/IX	20	11	101.5	30	120	(0.012)
33	9/IX	18	21	101.9	25	120	(0.014)
34	26/V	21	11	101.2	32	60	(.02)
34	9/VII	23	8	99.2	61	60	(<0.01)
34	23/VII	21	17	101.1	43	60	(<0.01)
34	8/IX	19	11	101.4	30-40	60	.07

Table 1 (cont'd)

House #*	Date (1981)	Indoor T(°C) %RH	Outdoor T(°C) %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)
35	9/VI	18	60	13	76	M	<0.25
35	23/VII	19	66	20	64	60	(.05)
35	7/VIII	18	70	12	98	60	(.06)
35	17/VIII	20	71	14	88	1,380	0.030
36	29/V	20	64	13	81	60	.06
36	2/VII	19	65	14	95	66	.08
36	9/IX	12	78	21	82	150	0.065
36	9/IX	12	78	21	82	150	0.060
37	8/VI	22	58	14	85	M	<0.25
37	28/VII	21	62	14	95	60	.09
37	7/VIII	19	74	11	95	60	0.09
37	21/VIII	24	54	16	68	230	0.065
38	10/VII	19	64	17	62	120	.038
38	13/VII	21	62	10	93	270	.031
38	15/VII	19	68	16	94	66	(.05)
38	26/VIII	21	72	16	70	300	.020
39	9/VI	20	59	12	80	M	<0.25
39	11/VIII	19	74	14	90	60	0.07
39	21/VIII	21	68	43	70	480	.063
39	22/VIII	24	65	21	50	1,440	.066
40	12/VI	20	60	4	88	60	0.06
40	7/VIII	21	73	13	90	120	.053
40	9/IX	20	72	12	78	60	(.05)
40	9/IX	20	72	13	78	60	(.05)
41	8/VI	20	63	13	85	M	<0.25
41	8/VII	20	62	18	70	60	(.03)
41	14/VII	18	65	13	73	60	(0.03)
41	19/VIII	20	74	14	79	1,440	0.068

Table 1 (cont'd)

House #*	Date (1981)	Indoor T(°C) %RH	Outdoor T(°C) %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)
42*	3/VII	21	56	17	52	145	(.017)
42	17/VII	25	68	18	62	180	(.010)
42	19/VII	21	60	16	62	60	(<0.01)
42	21/VII	17	64	13	79	90	(<0.01)
43	9/VI	23	58	12	22	M	0.25
43	7/VIII	21	70	14	90	60	(.04)
43	4/IX	20	70	13	79	60	(.04)
43	9/IX	22	70	12	79	60	(.06)
44	2/VI	23	51	14	35	60	(.01)
44	22/VII	19	62	15	76	60	(<0.01)
44	4/IX	21	65	15	76	60	(.04)
44	4/IX	21	65	15	76	60	(.04)
45	10/VI	18	55	6	100	M	<0.25
45	16/VII	19	60	18	73	60	(<0.01)
45	30/VII	17	66	16	62	60	(<0.01)
45	30/VII	17	64	16	62	170	(<0.01)
46*	22/V	24	45	16	41	60	(.04)
46	3/VI	23	55	18	45	60	(0.01)
46	15/VII	18	70	16	96	60	(.03)
46	25/VIII	20	70	9	83	60	(0.01)
47	20/V	19	50	15	40	60	(0.01)
47	9/VI	19	58	9	81	60	(.01)
47	1/VII	23	66	22	79	60	(.06)
47	4/VIII	28	58	22	68	180	.068
48	11/VI	19	57	6	92	60	<0.01
48	16/VII	20	64	19	69	60	<0.01
48	16/VII	20	64	19	69	60	<0.01
48	23/VII	22	60	19	69	60	<0.01

Table 1 (cont'd)

House #*	Date (1981)	Indoor T (°C)	Indoor %RH	Outdoor T (°C)	Outdoor %RH	At. Press kPa	Wind Sp. kph	Sample ¹ Vol L	Calculated ² formaldehyde conc (ppm)
49	11/VII	17	60	13	85	100.5	13	50	.08
49	7/VII	19	62	19	93	100.1	14	120	.14
49	4/VIII	22	62	23.5	60	102.1	28	180	.18
49	25/VIII	18	70	9	87	101.1	28	180	.15
50	17/VII	21	64	13	79	101.7	6	60	.08
50	18/VII	20	62	21	56	102.1	12	190	.035
50	25/VII	20	55	21	39	102.2	17	120	(.020)
50	25/VII	20	58	21	50	102.2	20	180	(.010)

NOTES: * Houses denoted by an asterisk are control houses not having UFFI.

1. A flow rate of 1.0 L min^{-1} was used for the NIOSH determinations listed in this Table. The symbol "M" denotes those determinations in which only the Miran 1A instrument was employed, and the lower limit of detection is taken to be 0.25 ppm.
2. Values indicated in parentheses represent those determinations for which the NIOSH criterion of a difference of 0.050 Absorbance units above the blank was not satisfied.

Table 2

EFFECT OF DIFFERENT FLOW RATES ON THE NIOSH DETERMINATIONS

Expt #	Sampling Rate	Length of Sampling* (min)	Calculated Formaldehyde ppm		
1	1.0 L/min	90	0.16	0.15 ± 0.01	
	0.75 L/min	90	0.14		
2	0.1 L/min	90	0.088	0.091 ± 0.003	
	0.75 L/min	90	0.094		
3	1.0 L/min	90	0.092	0.10 ± 0.009	
	0.75 L/min	90	0.11		
4	1.0 L/min	90	0.091	0.090 ± 0.001	
	0.75 L/min	90	0.089		
5	1.0 L/min	90	0.089	0.090 ± 0.01	
	0.50 L/min	90	0.092		
6	1.0 L/min	120	0.107	0.106 ± 0.001	
	0.50 L/min	120	0.105		

* These determinations were conducted in the same environments simultaneously as though replicates

Table 3

MIRAN ABSORBANCE UNITS VS NIOSH-DETERMINED LEVELS

House	Date of Test	Mean Miran Absorbance Units*	NIOSH ppm
4	1/VI	3.0	0.11
5	25/V	0	(0.04)
6	1/VI	4.0	(0.02)
7	1/VI	1.5	0.05
8	5/V	0	(0.04)
11	2/VI	2.5	(0.03)
13	15/VI	1.5	0.07
13	25/VIII	1	0.07
14	17/VI	3.5	(0.02)
15	11/VI	3.5	(0.01)
16	25/V	2.5	0.07
17	22/V	0	0.06
19	11/VII	2.5	0.09
20	20/V	1.5	(0.03)
20	9/VII	2.0	0.08
21	17/V	2.0	(0.01)
22	26/V	3.0	(0.01)
23	2/VI	3.0	0.09
25	11/VII	0	(0.01)
28	15/V	9.0	0.16
29	2/VII	10	(0.01)
31	22/V	0	(0.04)
32	15/V	3.0	0.10
34	26/V	2.0	(0.02)
36	29/V	4.0	0.06
40	12/VI	2.0	0.06
42	21/VII	0	(0.01)
44	2/VI	1.5	(0.01)
46	3/VI	2	0.01
47	15/V	1	0.01
48	11/VI	5	0.01
49	25/VIII	3	0.15

* Arbitrary units.

Table 4

DUPONT PRO-TEK^R C-60 FORMALDEHYDE AIR MONITORING BADGES: FIELD EVALUATION

Badge # ¹	RECIPIENT ²	LOCATION	ABS ³	TIME(h)	TWA(ppm)	NIOSH(ppm)
71961-C(M)	1	Body	0.071	24h	0.053	-
71962-C(M)	1	Wall	0.125	24	0.092	-
71963-C(M)	2	Wall	0.114	24	0.084	-
71964-C(M)	2	Body	0.187	24	0.138	-
71965-C(M)	3	Wall(b)	0.575	72	0.141	-
71966-C(M)	3	Body	0.36	72	0.088	-
71967-C(M)	4	Wall	0.725	24	0.534/0.489	-
71968-C(M)	4	Body	0.46	24		-
71979-C(M)	5	.	not returned			-
71980-C(M)	5	.				-
71111-C(M)	6	Body	0.147	24	0.108	-
71112-C(M)	6	Wall	0	24	0	-
71113-C(M)	7	Body	0.175	24	0.128	-
71114-C(M)	7	Wall	0.215	24	0.158	-
71051-C(M)	8	?	0.054	24	0.040	-
71052-C(M)	8	?	0.020	24	0.015	-
71847-C(M)	9	Body	0.068	24	0.050	-
71848-C(M)	9	Wall	0.105	24	0.077	-
71844-C(M)	10	Body	0.515	72	0.126	-
71845-C(M)	10	Wall	0.558	72	0.136	-
71115-C(M)	11	Body	0.330	26	0.224	0.090 (1h)
71116-C(M)	11(37)	Wall	0.355	26	0.240	
75787-C(P)	11	Wall	0.140	24	0.098	
71117-C(M)	12	?	0.080	24.5	0.058/0.068	0.066 (3h)
71118-C(M)	12(30)	?	0.030	24.5		
75783-C(P)	12	Wall	0.075	24		
71119-C(M)	13	Wall	0.190	24	0.139	0.018 (24h)
71120-C(M)	13(15)	Body	0.210	24	0.155	
(P)	13	Wall	damaged	24	-	
75761-C(M)	14	Wall	0.154	26.5	0.103	0.02 (3h)
75762-C(M)	14(26)	Body	0.086	26.5	0.057	
71057-C(P)	14	Wall	0.106	24	0.078	

Table 4 Cont'd

Badge # ¹	RECIPIENT ²	LOCATION	ABS ³	TIME(h)	TWA(ppm)	NIOSH(ppm)
75763-C(M)	15	Wall	1.10	168	0.116	
75764-C(M)	15(24)	Wall	0.92	168	0.097	0.150 (1h)
75765-C(M)	16	Body	0.136	25.25	0.095	
75766-C(M)	16(35)	Wall	0.128	25.25	0.089	0.030 (25¼h)
75784-C(P)	16	Wall	0.050	24	0.036	
75767-C(M)	17	Wall	0.390	24	0.287	0.063 (8h)
75768-C(M)	17(39)	Body	0.30	24	0.221	0.066 (24h)
75786-C(P)	17	Wall	0.115	24	0.085	
75769-C(M)*	18	Body	0.420	72	0.103	0.08 (1h)
75770-C(M)*	18(13)	Wall	1.115	168	0.105	
71071-C(P)	18	Wall	1.085	168	0.114	
71821-C(M)	19	not returned				
71822-C(M)	19(17)					
71058 (P)	19	Wall	0.22	24	0.16	0.062
71823-C(M)	20	Body	0.280	48	0.103	
71824 (M)	20(31)	Drape	0.240	48	0.088	0.12
71060 (P)	20	Drape	0.335	48	0.123	
71041-C(X)	20	Drape	0.245	168	0.0257	-
71825-C(M)	21	Wall	0.248	24	0.173	
71826-C(M)	21(14)	Body	0.575	24	0.428	0.064 (5½h)
75785-C(P)	21	Wall	0.130	24	0.096	
71827-C(M)	22	Body	0.20	24	0.15	
71828-C(M)	22	Wall	0.20	24	0.15	0.076 (3h)
71059-C(P)	22	Wall	0.305	24	0.225	
17829-C(M)	23	Wall	0.11	24	0.081	
17830-C(M)	23(1)	Body	0.073	24	0.054	0.045 (4h)
75790-C(P)	23	Wall	0.176	24	0.129	
75751-C(M)	24	?	0.078	24	0.057	
75752-C(M)	24(2)	?	0.094	24	0.069	0.029 (3h)
? (P)	damaged					
75753-C(M)	25	Body	0.215	27	0.141	0.04 (1h)
75754-C(M)	25(7)	Wall	0.185	27	0.121	
75755-C(M)	26	not returned				
75756-C(M)	26(9)					
75757-C(M)	27	Body	0.069	96	0.013	
75758-C(M)	27(46)	Wall	0.125	116	0.019	0.03 (1h)

Table 4 Cont'd

Badge # ¹	RECIPIENT ²	LOCATION	ABS ³	TIME(h)	TWA(ppm)	NIOSH(ppm)
75759-C(M)	28	Body	0.33	26.5	0.24	0.068 (24h)
75760-C(M)	28(41)	Wall	0.25	26.5	0.184	
75782-C(P)	28	Body	0.038	24	0.107	
71053-C(M)	29	Body	0.167	24	0.123	0.097
71054-C(M)	29(49)	Wall	0.218	24	0.166	
75788-C(P)	29	Wall	0.14	24	0.10	
71055-C(M)	30	damaged				0.010
71056-C(M)	30(42)	?	0.33	72	0.081	
71841-C(P)	30	Wall	0.155	72	0.038	
71849-C(P)	31	L/R Wall	0.69	171.5	0.073	(0.08)
71850-C(P)	31(19)	B/R Wall	0.83	171.5	0.087	0.090
71842-C(P)	32	Table/ vertical	0.99	0	0.105	0.138
71843-C(P)	32(20)	Table/ Horizontal	1.19		0.125	
71071-C(P)	33(20)	UFFI Wall	1.54	168	0.157	0.083 (25½h)
71073-C(P)	33	non UFFI Wall	1.45	168	0.148	0.109 (3h)
71074-C(P)	34(50)	Wall	0.285	144	0.035	0.035 (3½)
71075-C(M)	34	Wall	0.335	144	0.041	
71077-C(P)	35	Wall	0.675	168	0.082	0.059* (3h)
71078-C(P)	36	Wall	0.785	192	0.070	0.069* (3h)
71049-C(P)	37	Wall B/R	0.265	107	0.044	0.040 (1h)
71050-C(P)	37(20)	Wall	0.245	107	0.040	
71076-C(P)	38(20)	½" from Wall	1.22	147	0.146	0.088 (1h)
71048-C(P)	38	½" from Wall	0.80	147	0.096	

1. (M) = Badges mailed to and from homeowners; (P) = Badges carried to test homes, deployed and returned by field team.
2. Badges were mailed out at random. Numbers in parentheses refer to house number code used in general survey see Table 2.
3. Absorbances were determined on a u.v. spectrophotometer using 40 mm micro-cells and in a dual-beam mode with an unexposed badge solution serving as the blank.

Table 5

SOME HOME CHARACTERISTICS AND HIGHEST MEASURED NIOSH LEVEL

House #	Date of UFFI Installation	Age of House (years)	Type of UFFI	Highest NIOSH level (ppm)
1	1974	22	Rapco	0.045
2	1977	30	Borden	0.029
3	1979	20	Borden	0.058
4	1979	3	Rapco	0.11
5	1978	80	Rapco	(0.04)
6	1979	40	Borden	(0.04)
7	1978	44	Rapco	0.05
8	1979	80	Rapco	(0.04)
9	1979	60	Rapco	0.10
10	1978	60	Rapco	ND
11	1979	35	Rapco	0.076
12	1979	46	Rapco	0.11
13	1979	70	Rapco	0.085
14	1979	39	Rapco	0.081
15	1975	37	Borden	(0.04)
16	1979	42	Borden	0.11
17	1978	35	Rapco	0.07
18	1973	60	Borden	(0.05)
19	1979	60	Rapco	0.11
20	1979	60	Rapco	0.13
21	1976	140	Rapco	0.036
22	1978	50	Rapco	(0.01)
23	1979	140	Rapco	0.22
24	1979	31	Borden	0.36
25	Control	60	Control	(0.01)
26	Control	100	Control	(0.02)
27	1978	80	Rapco	0.066
28	1979	30	Rapco	0.16
29	Control	8	Control	(0.01)
30	1979	70	Rapco	0.066
31	1979	80	Borden	0.12
32	1978	60	Rapco	0.10
33	Control	100	Control	(0.014)
34	1974	45	Borden	0.07
35	1978	80	Rapco	(0.06)
36	1978	30	Rapco	0.08
37	1978	30	Rapco	0.09
38	1978	37	Borden	(0.05)
39	1979	40	Rapco	0.07
40	1977	60	Borden	0.06
41	1978	40	Rapco	0.068
42	Control	100	Control	(0.017)
43	1975	31	Borden	(0.06)

Table 5 Cont'd

House #	Date of UFFI Installation	Age of House (years)	Type of UFFI	Highest NIOSH level (ppm)
44	1974	36	Rapco	(0.04)
45	1978	45	Rapco	(0.01)
46	Control	32	Control	(0.03)
47	1978	80	Rapco	0.068
48	1978	50	Borden	(0.01)
49	1979	50	Rapco	0.14
50	1978	60	Borden	0.07

FIGURE 1

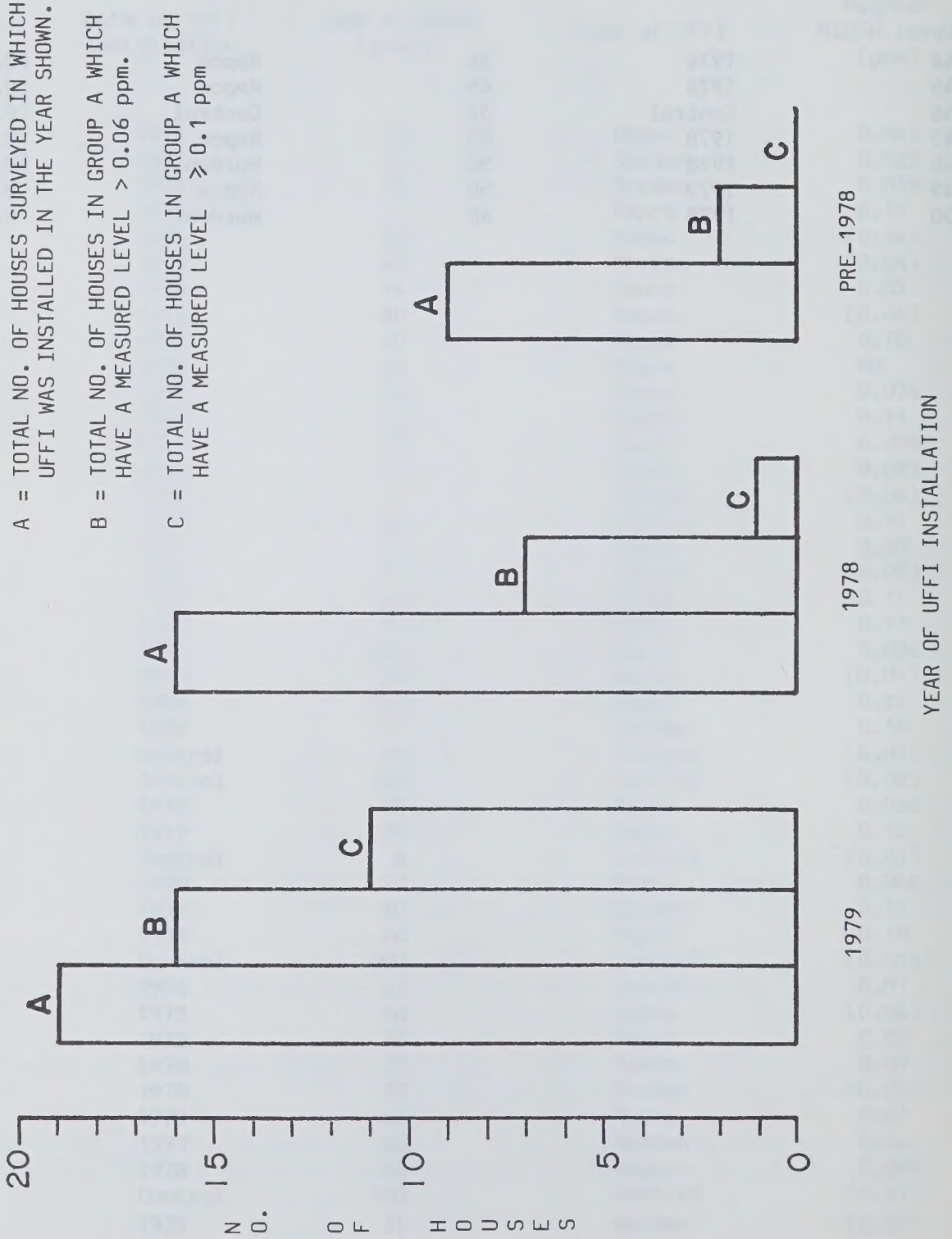
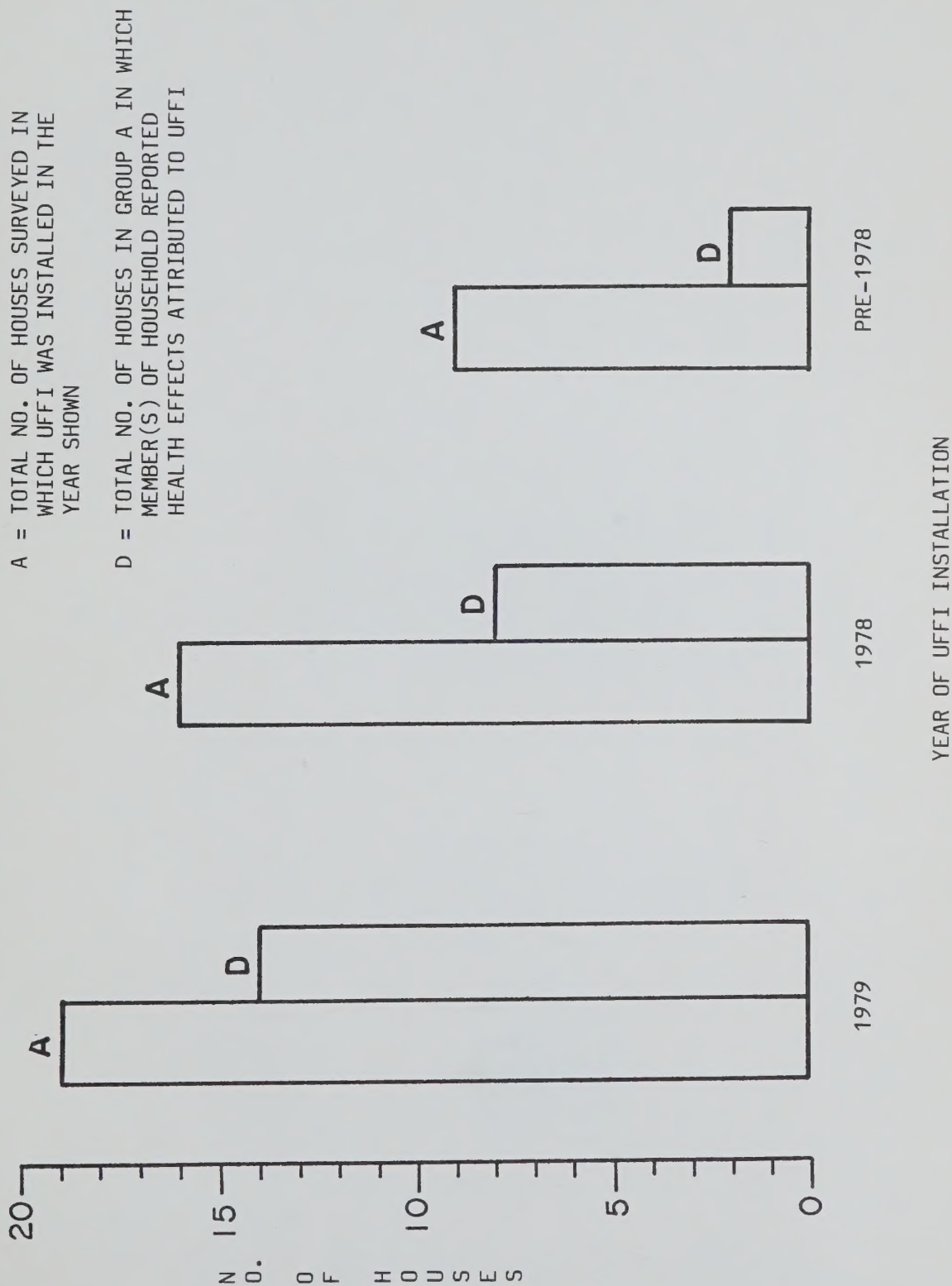


FIGURE 2



Doc.	Corporate Author:
No.	Canada. D. of H. & W.
CA	Not Indexed
HNW	Series: 82-EHD-83
82	Title: An investigation of
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